TECHNOLOGY BRIEF | FEBRUARY 2021

Maize and groundnut under conservation agriculture in Malawi. *Photo credit:* T. Samson/CIMMYT.

Conservation agriculture in maize–legume systems

Conservation agriculture is a promising technology for supporting sustainable increases in productivity. It helps farmers achieve more reliable and often higher yields while reducing production costs, increases dietary diversity, improves soil structure and fertility, maximizes nutrient- and water-use efficiency, and controls some pests and diseases.

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Description of the technology

Conservation agriculture is a crop management system based on three main principles: a) minimum soil movement (no soil inversion, i.e. no tillage); b) surface cover with crop residues and/or living plants; and c) diverse crop rotations or intercropping strategies. The most significant benefits will be achieved when all three principles are applied at the same time. The technology can be supported and improved with additional crop management practices, including timely application of operations, precision of seeding, adequate and sufficient application of nutrients (in the form of inorganic fertilizer, manure, and/or compost), and efficient control of weeds and pests, including the use of herbicides.

In Malawi and eastern Zambia, manual conservation agriculture systems are practiced with maize by making small planting holes with a pointed stick (dibble stick) or hoe. The seed is then planted in rows at a spacing of 25 cm between plants and 75–90 cm between rows. For rotational legumes, the spacing can be halved (to 37.5–45 cm between rows, while maintaining in-row spacing at 25 cm) to make full and more efficient use of the land area. This close spacing cannot be achieved in a conventional ridge tillage system, which is confined to a row spacing of 75–90 cm.

Cereals and legumes can also be grown as intercrops under no tillage in the conservation agriculture system.

Key messages

Yields:

Conservation agriculture has the potential to significantly INCREASE CROP YIELDS after 2–5 cropping seasons (by up to

99% on average, and up to

140% in drought years)

Soil erosion:

Can be **reduced** by up to 64%

Labor:

Reduction in **manual labor** of 25–35 labor days per hectare per cropping season

Water-use efficiency:

Greater **infiltration** and soil **moisture retention** can **increase** WATER PRODUCTIVITY **by 20–50%** after only 1–2 cropping seasons

Farmer Grace Malaitcha, from Zidyana, near Nkhotakota, Malawi at her maize plot which she cultivates using conservation agriculture (CA) practices. *Photo credit:* Patrick Wall/CIMMYT.

While the biophysical benefits in terms of improved soil structure and fertility will be achieved over several cropping seasons, farmers are likely to improve their food security and incomes as a result of higher yields after only two seasons, with reduced labor demand for land preparation and weed control.

Conditions that favor uptake

Agro-ecological conditions: Conservation agriculture systems are used currently by farmers cultivating a wide range of crops under many different types of soils and environments. The greatest improvements over conventional tillage occur in water-scarce environments. Conservation agriculture is also most beneficial where farming is subjected to labor or power constraints (animal or tractor), and where environmental degradation has resulted in accelerated soil erosion and low soil fertility. Heavy soils requiring a laborious tillage process are also suited to minimum or no tillage.

Livestock: Conservation agriculture systems are highly successful where there is little livestock pressure, since crop residues can be left to cover the soil surface rather than used as fodder. However, where livestock is more common and crop residues are required as fodder, there may be trade-offs between feeding the residues to livestock or retaining them on the soil surface. Mixed crop–livestock farmers can start conservation agriculture by using no tillage on a small part of the farm where they can add sufficient crop residues. Once the plots under conservation agriculture are established and yields have increased, farmers can use part of the crop residues for feed and part as ground cover, starting another small no-tillage plot and eventually expanding it to other areas of the farm. Conservation agriculture stops the practice of burning, thereby reducing carbon emissions.

Access to and availability of markets: The requirement for crop rotation to increase soil fertility, and reduce pest and diseases creates diversity by introducing leguminous crops, but also means that farmers need access to legume seed and markets for their produce. A lack of access to input/output markets can therefore hamper uptake of the crop rotation component by farmers living in remote areas with poor road infrastructure.

Alignment with household resource endowments

Conservation agriculture systems can be applied equally by small-scale farmers with a limited land area and larger-scale farmers that have access to draft or tractor power. Producing large amounts of biomass requires application of sufficient nutrients through compost, manure, or inorganic fertilizer. Farmers who are unable to purchase fertilizer (due to lack of access, subsidies, or cash) may therefore not achieve the maximum potential benefits.

Necessary ingredients for implementation

Labor: Manual conservation agriculture systems require only a pointed stick to plant maize under the prevailing conditions without having to till the soil. Where animal traction is common, the dibble stick can be replaced by an animal-drawn ripper.

Soil management: A key ingredient is the availability of plant biomass to cover the soil surface and retain soil moisture. This is easily obtainable in agro-ecologies where farmers neither burn crop residues nor feed them to livestock.

Crop management: Conservation agriculture requires crop diversification by rotating or intercropping maize with legumes or other cash crops. This is essential to reduce the spread of pests and diseases. Maize–legume intercropping is particularly beneficial; the legumes not only add nitrogen to the soil, they also provide nutritious food and are an additional source of biomass to use as mulch. Farmers with a rather small land area available should practice intercropping instead of crop rotation. The most suitable legumes for intercropping are pigeonpea and cowpea. In cooler climates they can also intercrop beans with maize. New research shows that farmers can grow two legume crops at the same time using the 'doubled-up' legume system (https://hdl.handle.net/10568/108796), without suffering from maize yield loss.

Weed control: This is critical when farmers convert from conventional to conservation agriculture. Without weed control through tillage, farmers need to apply a comprehensive weed control strategy to avoid yield penalties. This could entail rotations with competitive legume species, judicious use of herbicides, and/or more intensive manual weed control, at least in the first years of conversion until the weed pressure drops.

New mindset: Conservation agriculture requires a new way of planting crops without previous ploughing. This can be challenging for smallholders, extension agents, and researchers, at least in the beginning, and may require long-term testing and demonstration to convince users of its merits.

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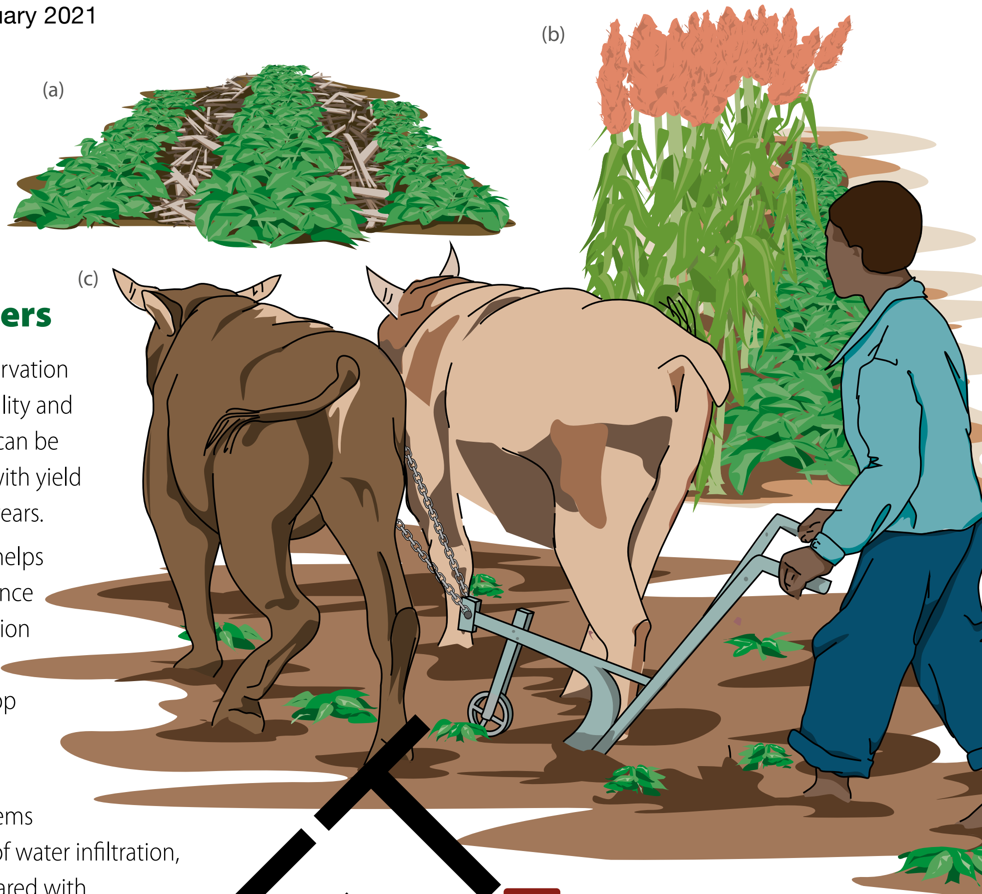
Adaptation possibilities

Most staple crops can be grown successfully under manual conservation agriculture. In Malawi and Zambia, the technology was tested successfully with maize, sorghum, cowpea, soybean, bean, cotton, sunflower, and tobacco. Even crops such as groundnut and cassava can be produced under conservation agriculture, although harvesting such crops causes considerable soil movement. Green manure/cover crops, shrubs, and leguminous trees are also suitable for cultivation under conservation agriculture and have proven effective in improving degraded landscapes, producing high-quality animal fodder, and supporting the sustainable productivity of multi-crop systems. The maize–pigeonpea intercropping system, for example, has been adopted widely in southern Malawi and has proven successful as a source of food security and income.

Where was the technology validated?

The technology was validated extensively in southern and central Malawi (Balaka, Dowa, Machinga, Nkhotakota, Salima, and Zomba) and eastern Zambia (Chipata, Lundazi, and Sinda) through long-term conservation agriculture trials. As a component of climate-smart agriculture, no-tillage systems have expanded significantly in recent years and it is estimated that more than 1 million farmers in Malawi and Zambia have adopted conservation agriculture.

The 3 basic principles of conservation agriculture: (a) crop residue retention, (b) crop rotation or intercropping, and (c) minimum soil disturbance.



Potential benefits to users

Food security and incomes: Conservation agriculture leads to improved soil fertility and therefore to higher productivity. Yield benefits can be significant after two to five cropping seasons, with yield increases of up to 140% measured in drought years.

Crop diversification: The technology helps farming families to diversify their diets, since farmers usually plant leguminous crops in rotation or as intercrops with their cereals. In long-term on-farm trials this led to an increase in Crop Diversification Index on average from 0.4 to 0.5 (+25%) and a higher Food Consumption Score.

Water-use efficiency: No-tillage systems permit three to five times higher rates of water infiltration, raising soil moisture content by 25–50% compared with conventional tillage. This explains why the technology performs best in conditions of water scarcity.

Soil structure and fertility: Soils managed under conservation agriculture have higher biological activity with an increased concentration of earthworms, beetles, ants, and spiders. This provides superior biological control of insect pests, such as the recently introduced Fall Armyworm. Soil erosion can be 64% less in no-tillage systems, leading to decreased siltation of dams and rivers, and halting soil degradation.

Soil carbon: Over time, there is a gradual increase in soil carbon (a 45% increase was measured in five years at the Chitedze Research Station, Malawi), although this depends on the residue management practice and the agro-ecological environment.

Labor: There is a reduced labor demand for land preparation (15–25 labor hours per hectare less) and weeding (15 labor days per hectare less when herbicides are used). This gives farmers a higher gross margin by up to 260%. If controlled effectively and seeding is prevented, weed populations decrease after the first two or three seasons. Achieving the same harvest with less labor preferentially benefits women, who may use their time to perform more profitable tasks.

Things to worry about

Farmers are continually balancing risks against opportunities. Moving to conservation agriculture requires careful evaluation and encouragement over several seasons, since the benefits are not immediate.

Livestock: There may be a trade-off between feeding crop residues to livestock and leaving the biomass on the soil surface to improve soil fertility.

Price fluctuations: Diversification to legume rotations or intercropping as cash crops can be risky due to fluctuating market prices.

Weeds: These can be troublesome in the early stages of conservation agriculture and may require additional labor and/or use of herbicides. However, if prevented from seeding, weeds will diminish after two or three seasons.

Soil organic matter: Breakdown of organic amendments in soils of low fertility may limit nitrogen availability to the plants due to proliferation of soil organisms (known as 'nitrogen lock-up'). This may affect initial plant growth. Careful nutrient management and rotation with leguminous crops can overcome this issue.

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The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-for-development projects supported by the United States Agency for International Development as part of the U.S. government's Feed the Future initiative. Through action research and development partnerships, Africa RISING will create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base. The three projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads an associated project on monitoring, evaluation, and impact assessment.

Africa RISING website: **https://africa-rising.net**

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